CAL POLY
SAN LUIS OBISPO
CORPORATION

October 27, 2016

Defense Technical Information Center
8725 John J Kingman Road, Suite 0944
Fort Belvoir, VA 220600-6218

RE: Contract Number N00014-15-1-2321
Assessment of Marine Coatings at a Central California Static Immersion Test Site
Principal Investigator: Dean Wendt

Greetings:

Please find attached the following report:

- Final Technical Report with SF298

Thank you.
Sincerely,

Leslie Rebik
Contract & Grant Analyst
Sponsored Programs Office
Cal Poly Corporation

REPORT DOCUMENTATION PAGE

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Contract Information

Contract Number	
Title of Research	Comprehensive Assessment of Marine Coatings in the Field.
Principal Investigator	Dean E. Wendt
Organization	Cal Poly, San Luis Obispo

Abstract

Cal Poly focused on biological assessments of nontoxic, foul-release and anti-fouling coatings to expedite the down-select process of new coatings. We utilized a suite of field tests to assess the performance of coatings provided to us from collaborators within the coatings testing program. Additionally, we participated in the intersite calibration study and collected ocean water quality parameters to be used to better characterize the biofouling community in relation to coatings and their performance. During the last grant period we tested 37 coating formulations and provided 16 technical reports about the performance of these coatings. Our water quality station has been functional for nearly the entire grant cycle. We are working to test the relationships between the recruitment of fouling organisms to intersite panels and water quality parameters. The static immersion site operated by Cal Poly provides a unique temperate marine environment for the testing of novel coatings within the coatings testing program.

Technical Section

Broad Goal

The overall goal of our work is to expedite the down-select process used to develop nontoxic, foul-release coatings through laboratory assays and field testing. We continually work to improve current and develop new methodologies for assessing novel coatings.

Technical Objectives

Objective 1: Our main objective was to provide comprehensive biological assessment of experimental marine coatings through quantitative and qualitative evaluation of coating performance. We used field-based assays to address the following: 1) the ability of the experimental coating to deter attachment of marine organisms by measuring percent of biofouling coverage; 2) the ease with which attached organisms are removed by measuring critical removal stress of barnacles and other hard fouling organisms, and by using water-jet to measure the pressure at which organism remove from coatings; and, 3) the ability of the coating to remain intact and prevent eventual corrosion of the

underlying surface in a cool-water, temperate marine environment at our static-immersion site in Morro Bay, California.

Objective 2: Our second objective was to continue to participate in the ongoing intersite calibration study.

Objective 3: Our last objective was to conduct additional analysis using our data on environmental parameters to explore which variables (e.g., temperature, salinity, chlorophyll) can be used as predictors of recruitment of fouling species.

Technical Approach

Objective 1: Assessment of experimental marine coatings

We used several approaches to meet our broad objectives of screening emerging coatings for their efficacy as foul-deterrent and foul-release surfaces. In general, the approaches we used include:

- Field assessment of coatings in a cool-water, temperate environment, including:
    - Foul-resistance
    - Critical removal force and waterjet
    - Long-term tests of coating durability

Field Assessment

Panels sent to us were exposed in a rack system that was suspended below a static immersion dock. Panels were generally exposed between one to 18 months depending on season and the experiment being conducted. At regular intervals the panels were assayed for biofouling coverage, water-jet testing, and force gauge removal testing. Percent coverage was calculated by first taking a digital photograph of the panel and then, using digital image analysis, determining the amount of the panel covered by fouling. Water-jet testing was done as outlined by Swain and Schultz (1996), using the water-jet apparatus described therein. The water-jet was trained on the panel and the entire area of the panel was sprayed, and the pressure was increased incrementally. The type and amount of fouling removed was recorded before testing and after each pressure was applied. Lastly, we used a handheld force gauge to remove barnacles and encrusting bryozoan (EB) colonies in shear from the face of the panel according to ASTM 5618. The mean force necessary to remove barnacles and EB colonies was compared among coatings using a standard one-way ANOVA (Fig. 1 and 2).

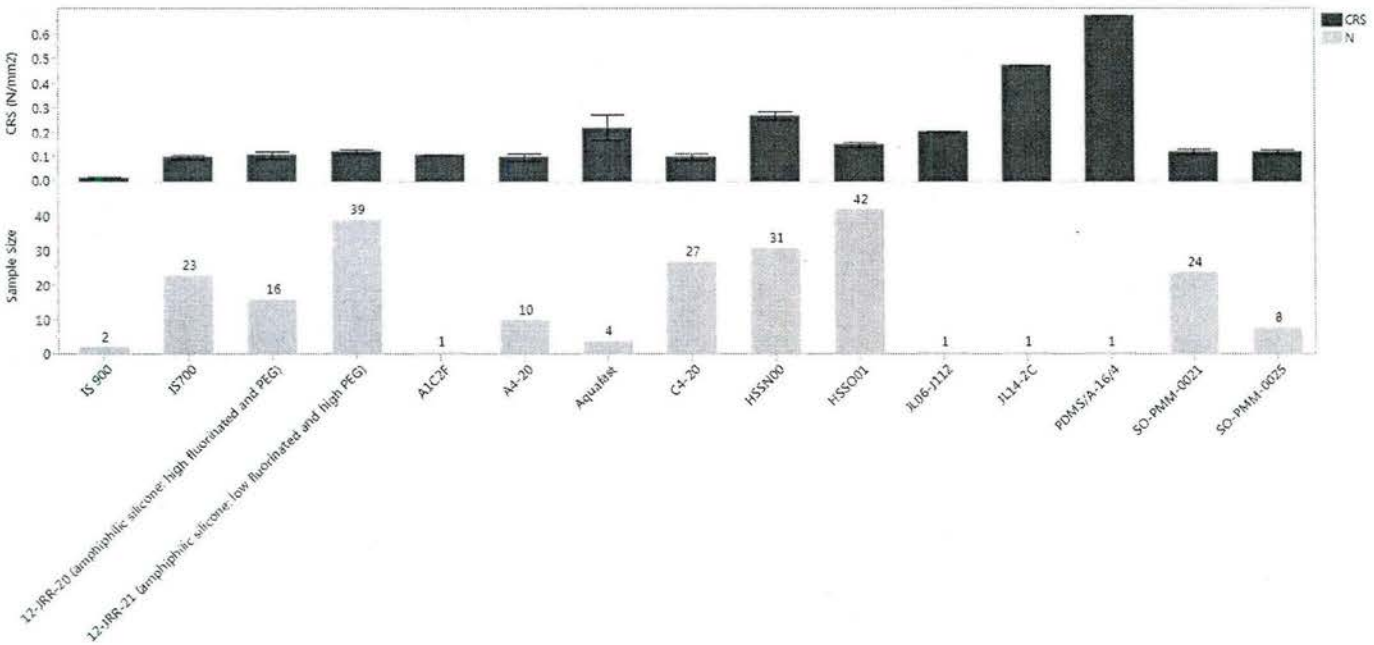

Figure 1 Critical removal stress and sample size of barnacles removed from test coatings using a hand held force gauge. Data are from barnacles pushed between June 2015 and September 2016. Error bars represent one standard error of the mean.

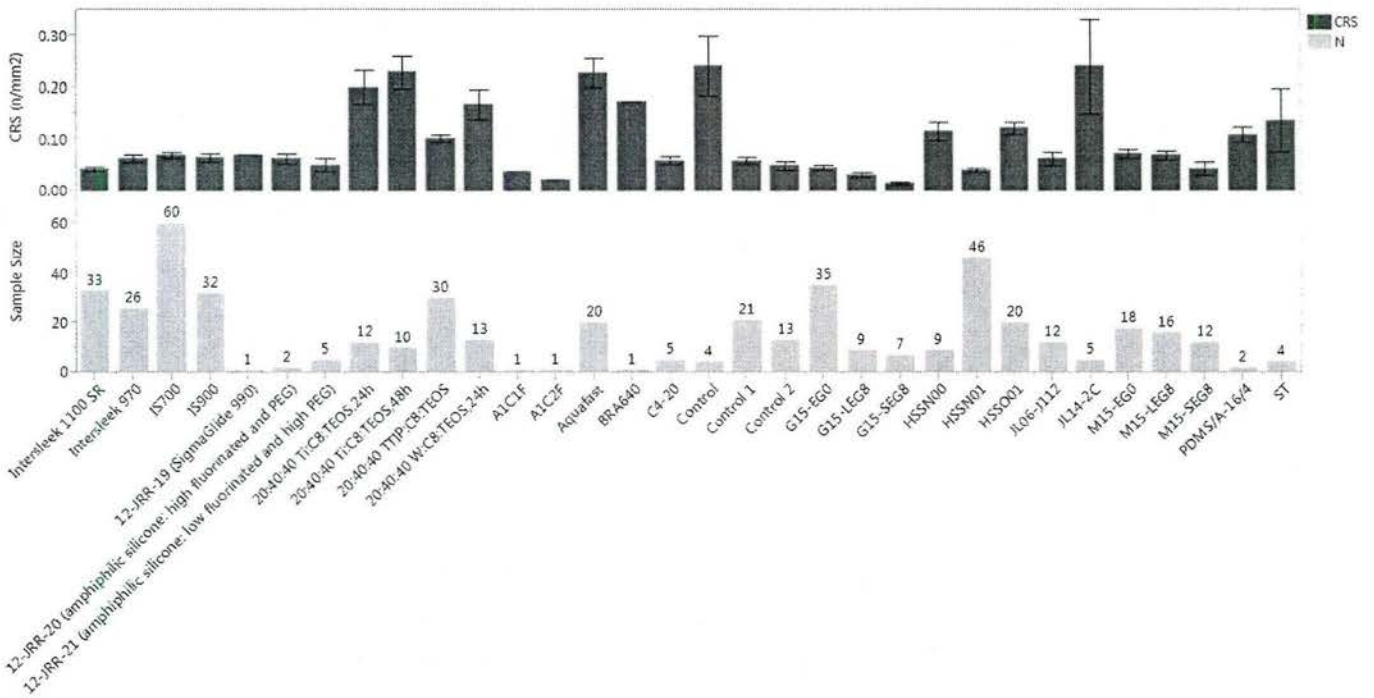

Figure 2 Critical removal stress and sample size of encrusting bryozoan colonies removed from test coatings using a hand held force gauge. Data are from encrusting bryozoan colonies pushed between June 2015 and September 2016. Error bars represent one standard error of the mean.

Objective 2: Intersite calibration study

We have worked in collaboration with Eric Holm, Mike Hadfield, Geoff Swain and Serena Teo to provide intersite calibration field testing. Each site was supplied with four replicate panels (painted back and front) coated with antifouling or foul release coatings. Panels were arranged at random within each block. Consistent with the intersite calibration protocol, we also exposed (3) PVC panels each month to use as a reference of larval recruitment. The anti-fouling coating panels were inspected monthly and fouling was quantified using standard procedures. Anti-fouling panels were replaced without disturbing the fouling community. The PVC panels were assessed for larval recruitment and then replaced with new panels each month. Foul-release coatings were allowed to accumulate fouling organisms until the hard fouling organisms reached a certain size. At this point the hard fouling organisms were removed using standard ASTM procedures. Adhesion of slime was also tested using the water-jet procedure. The percent coverage of slime for up to three, 3 cm x 3 cm patches of slime was visually estimated one each side of each panel. These patches were then sprayed at 20 psi (the PSI corresponding 23 Pa for our water jet apparatus) and the percent coverage of slime was re-assessed. Photographs of panels were taken and the coverage was determined using a 60 point grid generated in CPCe software. Visual assessments of PVC panels were conducted and used to assess long-term changes in the biofouling community structure from 2012 - 2015 (Fig. 3). Of particular interest, there has been very low recruitment of barnacles since August 2015.

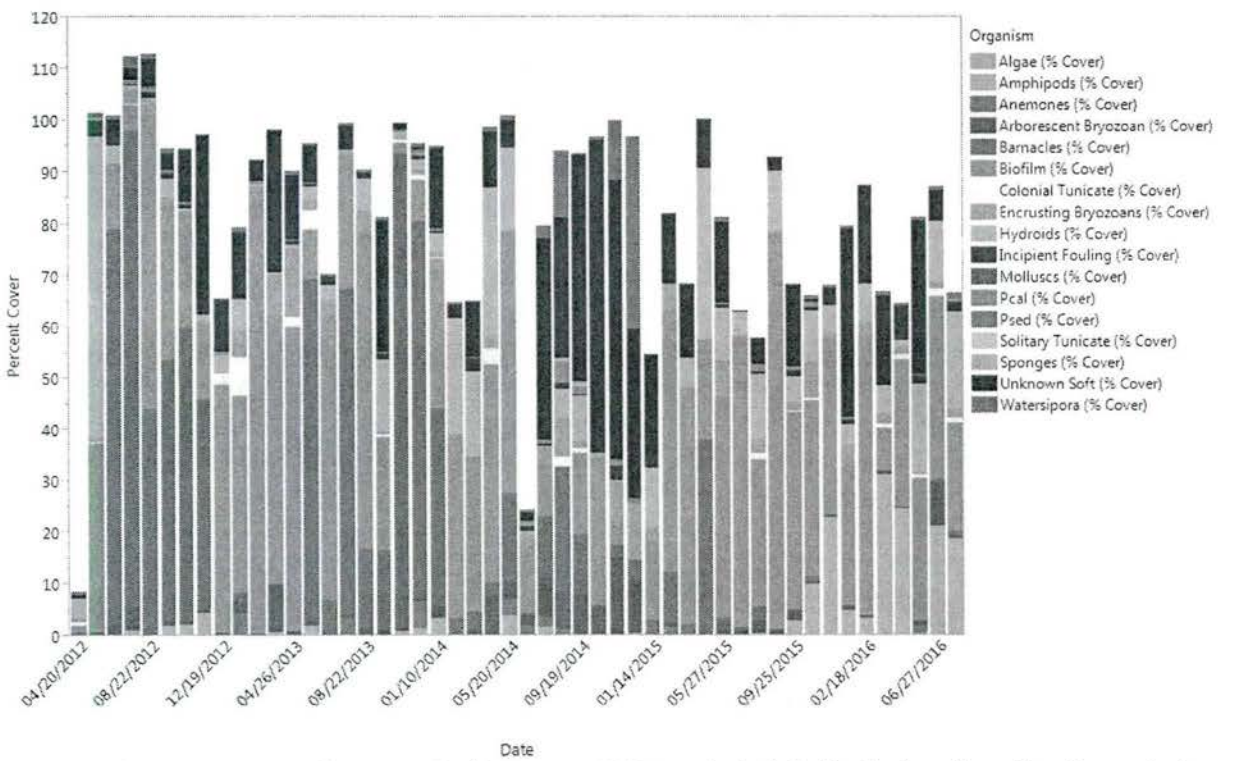

Figure 3 The percent cover of common fouling taxa on PVC panels included in the intersite calibration study from April 2012 – July 2016. PVC panels were switched out monthly.

Objective 3: Monitoring ocean water quality parameters

Field-testing consisted of immersing panels off of the Cal Poly static immersion dock in Morro Bay, California. Morro Bay is a cool water, temperate marine environment and thus the fouling community associated with our static test site is different than subtropical and tropical communities. To better track changes in physical parameters at our field site we installed a water quality array that records water quality variables every 15 minutes. The variables recorded by the water quality array included temperature, tide, salinity, water velocity, chlorophyll level, nitrate concentration, and turbidity. These data were uploaded to a server through a telemetry system and were archived for future use. Researchers can access data online or through direct requests (see www.slosea.org). We collected data continuously for 93% of the grant period (July 2015 – September 2016). In addition to understanding the physical environment at our site, we have completely characterized the fouling community by doing extensive surveys. All species recorded in our surveys can be accessed through an on-line database (see www.slosea.org). It should be noted that the equipment array, the invertebrate inventory, and the website resource were all funded through external grants outside of the ONR program.

Progress Statement Summary

1. Evaluated efficacy of 141 surfaces totaling 37 coating formulations using static field exposure;
2. Produced a total of 16 technical reports for PI's within the program;
3. Completed 15 months of testing of intersite calibration panels using CPCe point grid counts, waterjet, and critical removal stress of hard-fouling organisms;
4. Tested the CRS of 243 barnacles and 470 encrusting bryozoan colonies from 36 coating formulations;
5. Obtained water quality data from an array near our static immersion test site. This site was operational for 93% of the funding cycle;

Summary Statement

The overall goal of our work was to use field testing to expedite the down-select process used to develop nontoxic, foul-release coatings and to develop new methodologies to test the performance of foul-release coatings. We have met our deliverables on the project by; 1) assessing novel coatings in the field, 2) testing coatings for the latest round of intersite calibration, and 3) collecting continuous water quality parameters that can be used to asses relationships between these parameters and the temperate fouling community.

Supported Individuals:

Undergraduates: 6 (3 female and 3 male)

Technicians: 1

Publications:

Galhenage, Teluka; Hoffman, Dylan; Silbert, Samantha; Stafslien, Shane; Daniels, Justin; Miljkovic, Tatjana; Finlay, John; Franco, Sofia; Clare, Anthony; Nedved, Brian; Hadfield, Michael; Wendt, Dean; Waltz, Grant; Brewer, Lenora; Teo, Serena; Lim, Chin-Sing; Webster, Dean (accepted). Fouling-release performance of silicone oil-modified siloxane-polyurethane coatings. ACS Applied Materials & Interfaces

Price, H.L., Gohad, R., Mount A., and Wendt, D.E. (2017). Investigation of larval settlement pathways in the marine bryozoan, *Bugula neritina*. Journal of Experimental Marine Biology and Ecology. 486:69-76.

Stafslien S.J., Sommer S., Webster D.C., Bodkhe R., Pieper R., Daniels J., Vander Wal L., Callow M.C., Callow J.A., Ralston E., Swain G., Brewer L., Wendt D., Dickinson G.H., Lim C-S., Teo S.L-M. (2016) Comparison of laboratory and field testing performance evaluations of siloxane-polyurethane fouling-release marine coatings. Biofouling 32: 949-968.